David MacKay, 'Plan C' (2009)

1. Purpose of the activity

To help figure out the numbers and do the arithmetic to evaluate policies; and to lay a factual foundation on energy consumption and production, to show which proposals add up.
Plan 'C': 'C' for 'consensus', and 'C' for 'constructive conversation'. Plan C is a suggested starting point for a single consensus plan. An energy plan that adds up.

2. Model / scenario description

a) Timespan and region	2050, UK
b) Scenario type	Backcasting, Quantitative – arithmetic, Normative, Expert, Whole system.
c) What the approach has been designed to achieve.	To fully decarbonise Britain by 2050 (other than some sectors such as agriculture, steel, concrete, aviation, and international shipping).
d) Description of modelling method	Arithmetic balance between energy consumption and production.
e) References, links	From: 'A Plan with a time-line' (Draft 3.2, July 21, 2009) available at http://www.inference.phy.cam.ac.uk/sustainable/book/tex/PlanC.pdf, additional to 'Sustainable Energy – without the hot air', available at http://www.withouthotair.com/.

3. Key Assumptions

a) carbon & energy prices	Not considered.
b) final energy demand	– Transport: electrification increases efficiency 4x, cancelled out in part by economic growth, net effect: halving of energy consumption. – Heat: improvements to buildings insulation and heat controls, new buildings require almost no space heating – Electricity: efficiency and numbers of gadgets increase, net effect that demand for consumer electronics is maintained
c) economic conditions	Not specified.
d) social conditions	Population constant.
e) learning rates	Linear growth of technologies.
f) technology costs	Financial costs are estimated using today's process for comparable facilities.
g) policies	Policy options discussed [SEWHA Ch 29] but not evaluated in terms of effects.

4. Outputs

(a) final energy demand overall	Consumption reduced from current 125 → 68 kWh per person per day by 2050 (i) Heat: reduced 40 → 30 kWh pppd (ii) Transport: reduced 40 → 20 kWh pppd [SEWHA p. 204-5]
(b) how demands were met by fuel	Energy sources and contribution in 2050: (see table below)
(c) power generation by technology	UK generation in 2050: (see table below) Including electricity imports gives total output 124 GW.
(d) role for bioenergy	– Supply 7.5GW heat from 15%of UK land with sustainable forests and willow and miscanthus plantations. – Negligible use of biofuels for transport. Main use of biofuels in a decarbonized-Britain plan should probably be in agricultural machinery, aviation, shipping, and long-distance road freight

(b) Energy sources and contribution in 2050:

Energy source	*Output (GW)*
Low carbon electricity	114
Pumped heat	40
Solar hot water	2.5
Solar in deserts, imported	10

(c) UK generation in 2050:

Source	*Output (GW)*
Wind	30
Clean coal	3.2
Tide	8
Nuclear	70
Waste	2.5
Total	**114**

(e) role of enabling technologies	– Smart demand management or storage or both, are essential on a very large scale for the expansion of wind and nuclear. The two main forms of demand that will be easily turn-off-and-on-able will be electric-vehicle-charging and electric heat-pumping. Wherever possible, buildings should have heat stores – the bigger the better – to help provide demand that can be moved in time by hours, days, or even months. – Five pumped storage facilities providing 10GW rapidly-adjustable source, along with the rapidly adjustable demand of the half-charged electric vehicles that are connected at any time (amounting to an easily-switch-off-and-on-able demand of 10 or 20GW), and the rapidly-adjustable demand of heat pumps for making hot water and heat pumps for winter-building heating, will allow the balancing of fluctuating demand and intermittent renewables. – Storage technologies deserve strong investment, because cheap storage will help any decarbonized energy plan, whatever its mix. – Interconnector to France increased from 2GW to 12GW by 2050. Also built: 5GW of interconnectors to Norway; 1GW to Denmark; and 1GW interconnector to Iceland, assuming that Iceland increases its hydroelectric capacity.
(f) extent of decentralised energy production and role of CHP	– No micro-CHP because heat pumps are better and allow decarbonisation. – Solar hot water panels deliver 2.5GW of average power in the form of hot water by 2050, assuming 16 million units, each 3m^2. – A potential benefit of decentralized power generation is the engagement and energy awareness it causes.
(g) costs of achieving goals	Calculating technology costs on similar basis to Plan M in SEWHA Ch. 28 gives £450bn as cost of switching from fossil fuels.

5. Key messages

- We build almost every zero-carbon technology we possibly can, as fast as we possibly can, starting right away.
- The plan reduces energy consumption by between 30% and 50% (depending how the accounting is done) by adopting super-efficient technology for the two biggest consumers – transport and heating.

Jonathan Radcliffe, ERP Analysis Team
October 2010